

Conduct Flow Field Measurements in Acrylic Models Using the Matched Index of Refraction (MIR) Technique

Project Number: 97-19

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Purpose

The MIR technique matches the light bending properties of a transparent flow model with the working fluid so that optical velocity measurements can be made in practically any flow passage. The purpose of CDDF 97-19 is to develop this technique so it can be used in the experimental analysis complex rocket engine flows.

Background

Clear acrylic models are routinely used in cold-flow testing for obtaining qualitative flow field information, but the use of nonintrusive measurement (without the introduction of a solid probe in the test section) like LDV and PIV allow the acquisition of quantitative information such as velocity profiles, turbulence intensities, and Reynolds stresses. However, both LDV and PIV require optical access to the flow region where measurements are required. Further, it is not sufficient that the models be merely transparent but near-optical-quality finish is required in order to obtain high fidelity data. This is usually accomplished through the use of optical quality glass windows for making the measurements. LDV and PIV are only marginally successful in obtaining good data in instances where the models have internal complexity. In the last decade or so, the matched index of refraction (MIR) technique has been successfully developed for making high quality flow measurements in transparent models especially with high internal complexity. Specially formulated fluid mixtures and precise temperature

control are used to match the refractive indices of the fluid and the model material. Coupled with external flat model surfaces, the experimenter can then use LDV and/or PIV to make flow measurements anywhere in the model, including flows near walls and other obstructions. Even complex passages, such as the flow between turbine blades, can be probed provided the blades are fashioned out of acrylic. This technique has so far been used in a laboratory environment and mainly used to study flows of academic interest.

Approach

The 2-year project is divided into three tasks:

1. Develop the capability to match indices of refraction,
2. Fine tune the technique on a simple model, and
3. Utilize the technique on an advanced model.

Accomplishments

- Working Fluid: A literature and vendor search found R.P. Cargille Laboratories, a chemical company that produces specialty fluids to the customers specifications. Our request was for a clear fluid with an index of refraction value of 1.49 at room temperature, low viscosity and cost, and not logistically or medically hazardous. Cargille produced a light hydrocarbon-based oil (the ingredient list is

proprietary) with a viscosity of 24 centistokes.

- **Flow Loop Preparation:** The loop being renovated had a centrifugal pump, but was not capable of handling the higher viscosity of the new working fluid. A new pump has been purchased and installed. During the installation, a problem was found with the pump's variable speed drive electronics. At the print date of this report, the repairs were not complete, holding up the introduction of the working fluid into the loop. Another task being delayed by the pump is the addition of a new control system. A contract was awarded to Innovative Controls, Inc., to provide a flow and temperature controller, as maintaining the temperature is critical for matching the index of refraction value. Innovative Controls, Inc., is ready to install the control system when the pump is operational.
- **First Application:** The first flow model, a three-dimensional sudden expansion geometry, has been fabricated.

Planned Future Work

After successful installation of the new pump and fluid:

- A temperature and flow control system will be installed, and detailed MIR operating procedures will be developed for the technique.
- The MIR technique will be used to obtain data on pipe flows with sudden expansion.
- A candidate propulsion test case will be selected, modeled, and experimentally tested with the technique. This may require a no-cost extension of the project into FY99.

Funding Summary (\$k)

20k of FY97 funds (75k) were carried over, giving the project a FY98 funding level of 75k. In FY98, 15k will go to USRA, NCC8-66.